FinnRA

Infrastructure management system preparation of case-study

Inception report

February 15th, 1993

Helsinki 1993

Finnish National Road Administration

Economic Development Institute, The World Bank

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Keywords infrastructure, management, pavement management, bridge management, optimization

Executive summary

This Inception Report for the preparation of the Case-Study for Transport Management Development Program, an Infrastructure Management System (IMS), includes project background, the initial findings, description of the Finnish Pavement Management System and Bridge Management System and the outline for the further execution of the Study. The agreements approved by both parties have been included as appendices in this report.

Chapters 1 and 2 describe the background and need of the Project and the organizational structure of the Project.

Chapter 3 outlines the current Pavement and Bridge Management Systems (PMS and BMS) used in Finland. Furthermore, outlines for the Infrastructure Management System and the tasks to be fulfilled in order to meet the objectives of the Study are listed.

The proposed Work Programme to complete the Study by the end of July 1992 is presented in Chapter 4 including the proposed dates for the submission of reports, documents and the computer software.

Contents

1 INTRODUCTION

The Memorandum of Understanding between the Government of Finland (GOF) and the Economic Development Institute of the World Bank (EDI) was signed in Helsinki, December 18, 1992. The MoU states the framework for cooperation of the both parties that would focus on a transport training program for senior sector managers and trainers from Republics of the Former Soviet Union (Annex 2). As part of the training program would be the Case-Study for Transport Management Development Program (TMDP).

The Terms of Reference for the Case-Study on Infrastructure Management System are attached as Annex 3. The Case-Study would be immediately used as training material for the TMDP.

The Finnish proposal is to introduce the existing Pavement Management (PMS) and Bridge Management (BMS) Systems and to modify them in order to optimize simultaneously bridges and pavements under the same budget and other constraints. As such the system has to comprehensively consider all the main expenditure items associated with the network under consideration, i.e. bridges and pavements in this case of road networks. Furthermore the system will incorporate discounted cash flow techniques, so that investment efficiency indicators can be estimated for each investment alternative associated with a pre-specified level of budgetary availability.

The case-study is financed by the Government of Finland. The total project cost is estimated to USD 200 000. EDINU would bear the additional costs to be incurred with the editing, translation, publication and diffusion of the Case-Study.

The contents of the case-study are

- update the six sub-models in the PMS to be included both the pavements and the bridges
- estimate and calculate the necessary condition data and user cost data for bridges and update that of pavements
- update the existing software for simultaneous runs of bridges and pavements
- optimize and estimate rates of return and other investment efficiency indicators for investments alternatives and program the software needed
- test and prepare documents of the software
- prepare reports and review results.

The case-study is expected to be completed by end-July 1993. At a latter stage, it is expected that the Case-Study would be integrated into the normal program of EDINU's activities worldwide.

This Inception Report summarizes shortly project preparation, project description and presents a research work program to complete the Case-Study.

2 PROJECT DESCRIPTION

2.1 Background

Dr. Pedro Geraldes, from the Economic Development Institute (EDI) of the World Bank, visited Helsinki from December 14 to 18, 1992 to, inter-alia, prepare with Finnish officials a proposed framework for cooperation between the Government of Finland (GOF) and EDI's Infrastructure and Urban Development Division (EDINU). The signed Memorandum of Understanding (Annex 1) summarizes the consensus reached during the Mission's visit. The framework for cooperation would focus on a transport training program for senior sector managers and trainers from Republics of the Former Soviet Union (FSU), especially the Russian Federation and the Baltic countries, and from selected Central and Eastern European countries. It would cover a period of three years, during which a total of nine activities (each lasting for up to two weeks) would be delivered in Finland for the benefit of about 180 senior managers and some 45 professors from Universities and sector Research Institutes. The training program would address transport policy and operational issues, with emphasis on pricing and resource mobilization, economic and financial analysis of capital investment projects, environmental assessment, liberalization and private sector development, and business administration.

The above issues would be aggregated under three product lines of training activities. A key component of the training program is a Transport Management Development Program (TMDP). Participant managers would be identified among public sector officials already involved, or likely to be involved, in the preparation and appraisal of transport investments financed by multilateral financial institutions, including the World Bank. Program contents would cover fundamentals of transport economics; the project cycle with emphasis on the economic, financial and environmental analysis of projects; infrastructure management systems; logistics management and procurement.

The strategy to be followed in the preparation of training materials for the TMDP emphasizes the use of computer-aided decision-making techniques, based on economic benefit-cost concepts. Among these techniques are management systems allowing for a rational allocation of resources to the development and operation of infrastructure networks, including (but not limited to) paved roads and bridges. Such systems basically allow for an economic-based optimization of network expenditures, subject to budgetary constraints, based on the analysis of the trade-offs between user and infrastructure costs.

2.2 The project

The chief aim of the assignment would be to upgrade the Pavement Management System (PMS) and the Bridge Management System (BMS), currently being used by FinnRA, in order to prepare a Case-Study on Infrastructure Management System (IMS) capable of meeting TMDP's training requirements. As such, the main objectives of the assignment are to

1 incorporate the quantification of Vehicle Operating Costs (VOC) into the BMS, toward the analysis of trade-offs between user and infrastruc ture costs

2 allow for the consideration of diverted traffic effects within the BMS, through the incorporation of a minimum-cost VOC algorithm
3 consolidate the PMS with the BMS, so that they can be jointly optimized under one budgetary constraint
4 prepare training documentation.

2.3 The study team

On behalf of the FinnRA the project will be supervised by Deputy Director, M.Sc., Raimo Tapio as a project manager. The other participants will be

Project secretary Helena Ruottinen
Project secretary Katri Toivonen
Bridge Engineer Veijo Kuusinen, M.Sc.
Bridge and Pavement Engineer Magnus Veijola, B.Sc.
Economist and Statistician Vesa Männistö, M.Sc.
Economist and Statistician Antti Kanto, Ph.D.
Software Specialist Jukka Kujansuu, B.Sc.
Software Specialist Mikael Stenmark, M.Sc.

On behalf of the World Bank the contact person will be Mr. Soto, Division Chief from the Economic Development Institute.

3 RESEARCH WORK PROGRAM

The primary objective of the Study would be to upgrade the Pavement Management System (PMS) and the Bridge Management System (BMS), currently being used by FinnRA, in order to prepare a Case-Study on Infrastructure Management System (IMS) capable of meeting TMDP's training requirements.

In the following, the basic features of PMS and BMS are presented. Moreover, the tasks of building up the Infrastructure Management System are described.

3.1 Highway investment programming system (HIPS)

Finnish National Road Administration has developed a comprehensive Pavement Management System, Highway Invesment Programming System, HIPS, for its 45 000 km of paved roads. This system is used by the Road Administration's central office in long-term and short-term planning of road investment.

The diagram (Figure 1) shows the system structure of the overall pavement management system. HIPS covers the network-level part of this management process.

The network-level system contains two parts: long-term pavement management and short-term pavement management. Figure 2 shows the structure and elements of this system.

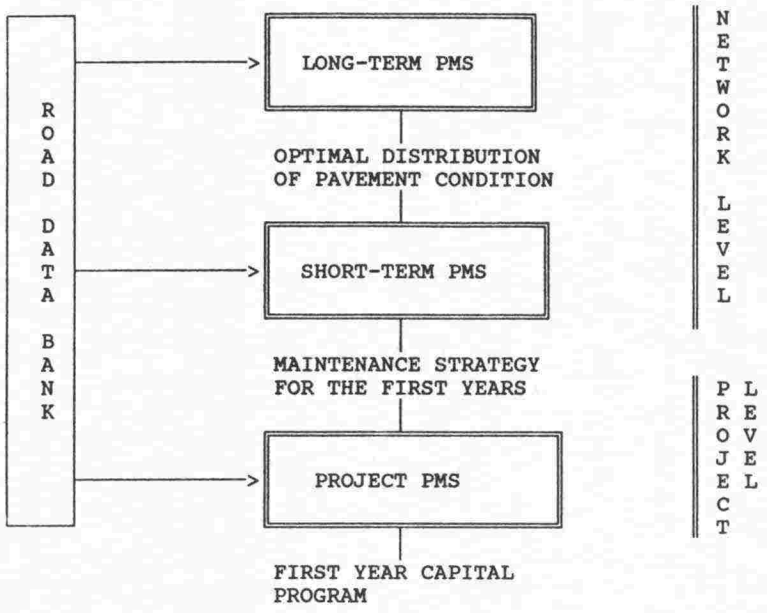


Figure 1. Pavement management process.

The economic optimization model consists of five basic elements, related to one another through a dynamic programming formulation:

- a probabilistic pavement deterioration model, describing empirically the changes which occur from year to year due to traffic, weather and rehabilitation
- a user cost model estimating economical effects caused by road roughness, rutting and defects
- a maintenance and rehabilitation cost model for each possible rehabilitation action
- the current network condition distributions
- various possible constraints on budgets and conditions.

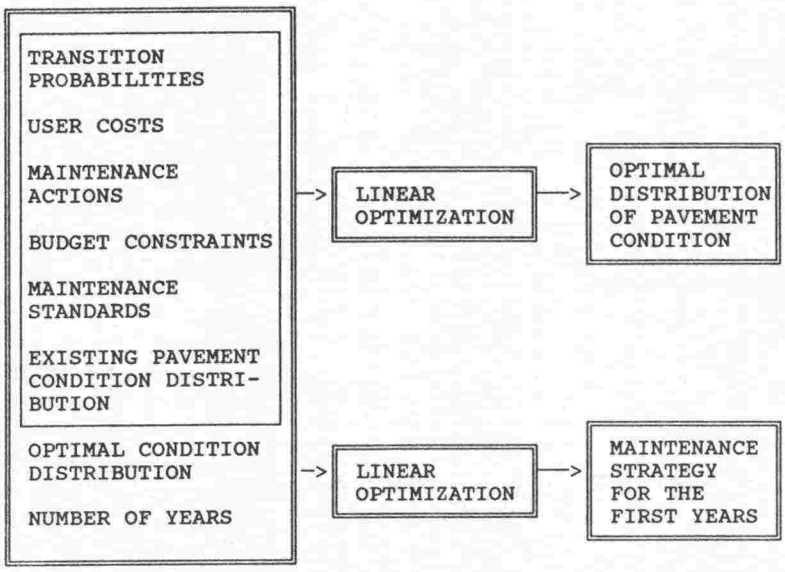


Figure 2. Network-level pavement management in HIPS.

To adequately reflect the variation of pavement deterioration and costs with traffic volume and climate, the highway network is divided into region/traffic volume class sub-networks. A completely separate optimization is performed for each one. By varying the effect of user costs from one sub-network to another, it is possible to evaluate the policy implications of various budget allocations among these sub-networks.

Road network conditions are presented by dividing pavements into various classifications according to their current condition. In the current model, each pavement section is classified along the following four dimensions:

- bearing capacity (5 levels)
- pavement distresses (3 levels)
- pavement roughness (3 levels)
- pavement rutting (3 levels).

Since each pavement section appears in exactly one of the classes, each of the above dimensions, each pavement section can be in one of 135 possible states at any particular time. The condition of the network overall is expressed by the distribution of all pavements among the states.

Under the influence of traffic and weather, a pavement deteriorates from year to year. These deterioration models are probabilistic Markov models, expressing the likelihood of transition from one condition state to another in one year. If no action is taken, pavements will tend to deteriorate to worse states along one or more of the four dimensions; but if a rehabilitation treatment is applied, the change is likely to be toward better conditions. In particular, actions which raise a road's structural condition (such as thick overlays) are likely to cause immediate improvements in roughness, and also make the road more resistant to future deterioration along these dimensions.

The Markov model, in principle, simulates the transitions among the 135 classes of roads over many years. Each year, the model evaluates the possibility of applying each of the eight possible rehabilitation actions, which range from do-nothing to heavy reconstruction, to each class of roads. The distribution of conditions in the next year depends on the current distribution of pavements among the states, and the selected action for each state. In each year, the user cost model estimates the user costs incurred by road users, and the construction cost model computes the costs incurred by a roadkeeper for the rehabilitation actions which are taken. The optimal strategy is the multi-year rehabilitation policy consisting of a rehabilitation choice for each road class for each year-which gives the lowest net present value of total (user + maintenance) cost.

This network-level dynamic programming model is solved by expressing it as a linear programming problem, solved by a specialized linear programming package, Hyper-Lindo.

The model is divided into a long-term steady-state component and a short-term component. The long-term component tries to find a distribution of pavement condition states which is economically optimal and sustainable from year to year indefinitely thereafter. The short-term model evaluates the strategy which makes the greatest possible amount of progress toward the long-term distribution each year.

The distinction between the long-term and short-term models is useful for policy makers, because the long-term solution sets an attainable long-term pavement condition level and long-term funding level, against which the accomplishments of the pavement management system can be measured. The short-term model, on the other hand, tells what actions are necessary in the next budget cycle and following cycles in order to accomplish the long-term goals.

The results of these analyses are useful in responding to strategic objectives such as the following:

- capital programming and budgeting
- estimating total budget needs
- allocating road investments among regions and road districts
- evaluating tradeoffs between various actions
- identifying impact of budget constraints.

3.2 Bridge management system

Introduction

Finnish National Road Administration has been developing a comprehensive Bridge Management System for its 12 000 bridges and culverts. This system will serve as a tool for analyzing long-term and short-term bridge maintenance policies.

The classification of bridge characteristics provides the basis for bridge management. The approach taken groups bridge structural members to highlight the most important types of bridge components and to yield information useful in network management. This approach first divides bridges into their primary subsystems, which are

- superstructure
- substructure
- deck
- bridge furnishing and other features.

Each of these subsystem groups is the divided further into specific categories. This division is shown in Figure 3.

For the Bridge Management System to support this classification, data on bridge material and condition has to be available. This is ensured by having a comprehensive Bridge Register, which currently produces all necessary data for Bridge Management.

The economic optimization model of bridges basically consists of the same five basic elements as in the case of pavements:

- a probabilistic deterioration model, describing empirically the changes which occur from year to year due to traffic, weather and rehabilitation
- a user cost model, which quantifiates Vehicle Operating Costs into the BMS, toward the analysis of trade-offs between user and infrastructure costs; at the same time, the model would allow the consideration of diverted traffic effects within the BMS, through the incorporation of a minimum-cost VOC algorithm
- a maintenance and rehabilitation cost model for each possible rehabilitation action

- the current network condition distributions
- various possible constraints on budgets and conditions.

The optimization part of Bridge Management System would be rather similar to that of pavements. The model is divided into a long-term steady-state component and a short-term component. The results gained from bridge management are similar to those of pavements, namely

- estimates of total budget needs
- allocation of resources among regions and road districts
- evaluation of tradeoffs between various actions
- comparison of different budgetary scenarios.

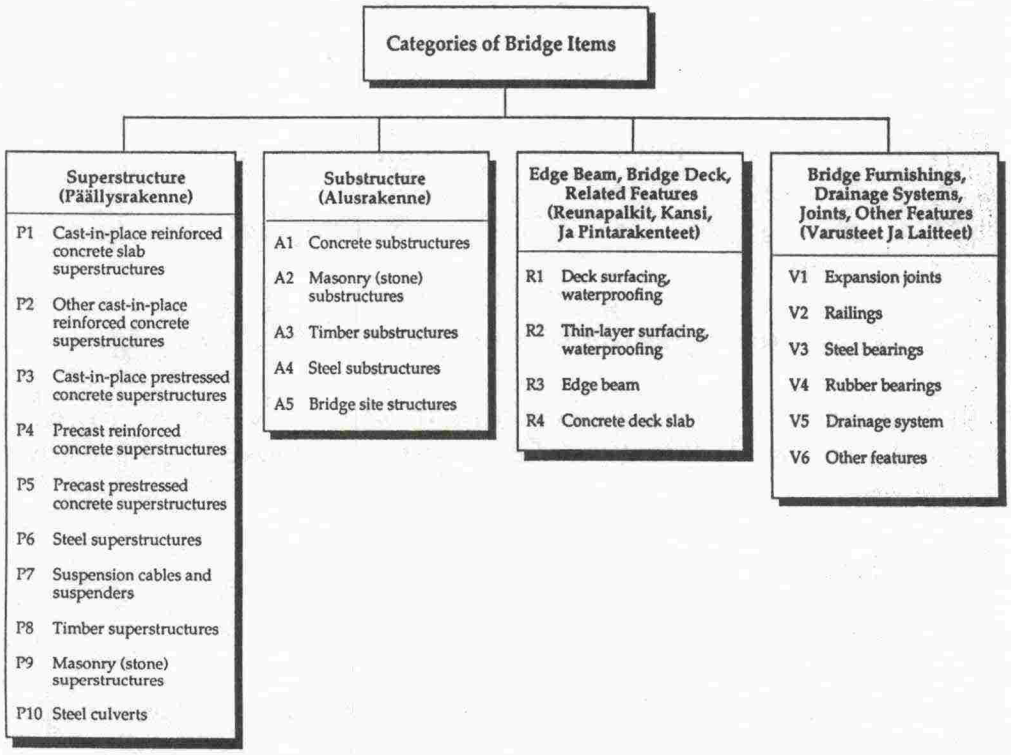


Figure 3. Categories of bridge items.

3.3 Infrastructure management system

The basic idea of this Case-study is that the current network-level pavement management system, HIPS, provides a starting-point for the Study. Shortly speaking, the asphalt-concrete part of HIPS-system will be used as such for pavements and bridges are incorporated to the system by using three of the six asphalt concrete submodels for bridges.

The preparation of the Infrastructure Management System will comprise the following main steps:

3.3.1 Input data preparation for pavements

The current data set of pavements will be updated to consist of the main road network of Finland, comprising some 12000 km's of roads. The main task is the calculation of the current condition distribution.

3.3.2 Bridge condition variables and classification

Bridge condition will be expressed by using four classified condition variables similar to those of pavements. Reinforced concrete bridges along main roads of Finland (5000 bridges) are used as an example data set.

3.3.3 Input data preparation for bridges

As soon as bridge condition variables and their classification is available, all necessary data for bridge management is collected. These data include

- current condition of bridges
- deterioration models and maintenance effect models
- maintenance actions and their costs
- vehicle operation and diverted traffic costs.

3.3.4 Preparation of current HIPS-system for bridges

This step includes software changes needed for the replacement of 3 asphalt concrete models by 3 bridge models.

3.3.5 Calculation of economical efficiency indicators

Current available economical indicators of HIPS are reviewed and new indicators are introduced. These include rates of returns, net present values and first year benefits, for example.

New software for these indicators will be programmed.

3.3.6 Testing and documentation of software

All parts of software are tested thoroughly. Necessary documents for further modifications are produced.

3.3.7 Analysis of results

The results gained from the new IMS will be carefully examined by the study group. Examples of results are attached to the final report.

3.3.8 Reporting

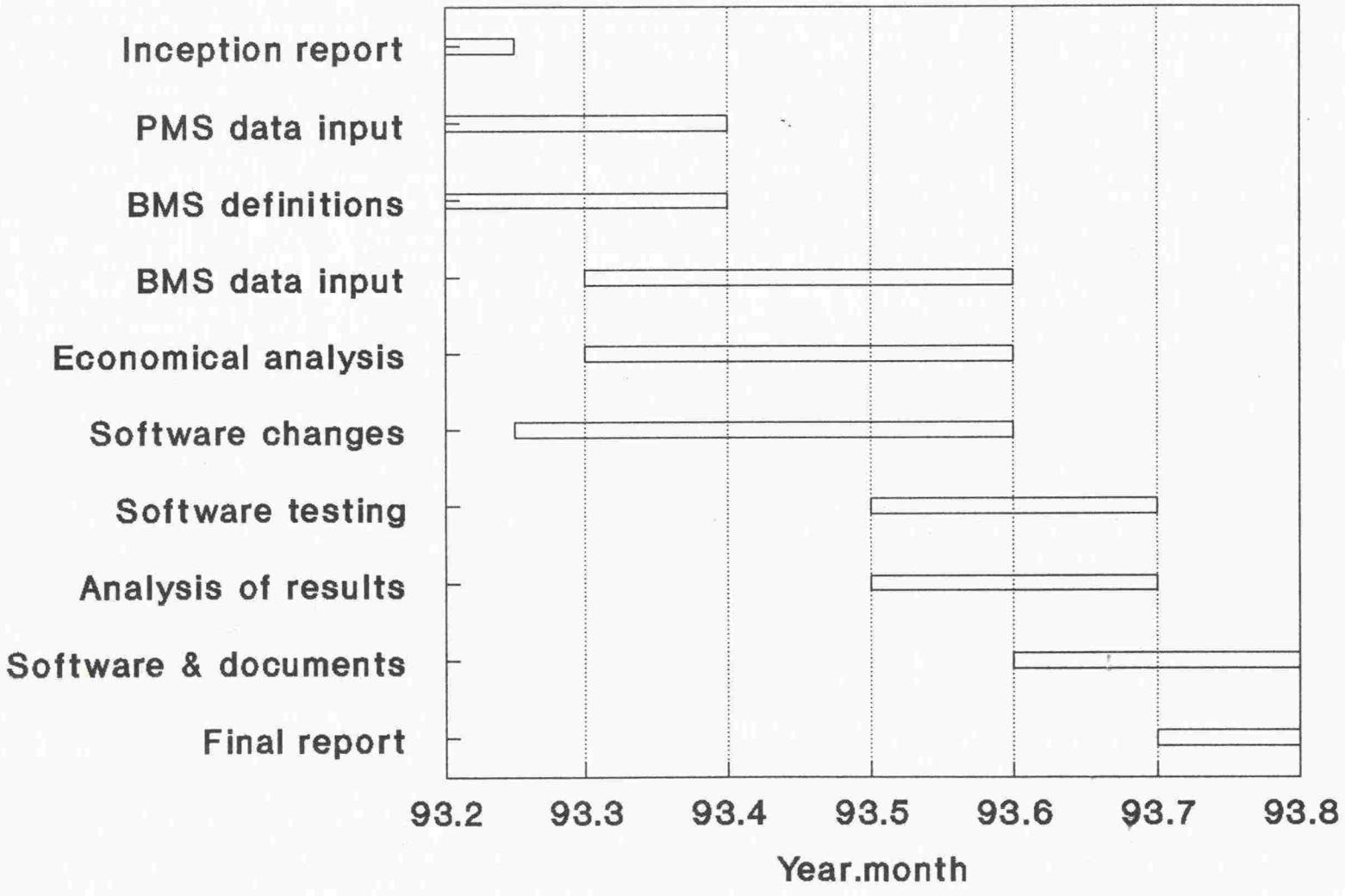
Main reports will be prepared in accordance with the following schedule:

- inception report by mid-February, 1993
- final report by end-July, 1993
- software package and necessary docu mentation by end-July, 1993.

4 TIME SCHEDULE OF THE PROJECT

See appendix 1.

Time Schedule of the IMS



APPENDIX 1

Memorandum of Understanding

Introduction and Background

1. Dr. Pedro Geraldes, from the Economic Development Institute (EDI) of the World Bank, visited Helsinki from December 14 to 18, 1992 to, inter-alia, prepare with Finnish officials a proposed framework for cooperation between the Government of Finland (GOF) and EDI's Infrastructure and Urban Development Division (EDINU). Dr. Geraldes' mission follows on contacts established during 1992, both in Finland and the U.S.A., between EDINU Higher-Level Management and Senior Officials from the GOF. The activities of the Mission were conducted in close cooperation with staff from the Ministry of Foreign Affairs (MOFA) and from the Ministry of Transport and Communications (MOTC), as well as from the Finnish National Road Administration (FINNRA) and its Institute for Highway and Maritime Education (IHME). The present Memorandum of Understanding summarizes the consensus reached during the Mission's visit which are subjected to further confirmation by the World Bank.

Objectives

2. The framework for cooperation would focus on a transport training program for senior sector managers and trainers from Republics of the Former Soviet Union (FSU), especially the Russian Federation and the Baltic countries, and from selected Central and Eastern European countries. It would cover a period of three years, during which a total of nine activities (each lasting for up to two weeks) would be delivered in Finland for the benefit of about 180 senior managers and some 45 professors from Universities and sector Research Institutes. The recommended targeting is aimed at the progressive internalization of the training effort within the beneficiary countries, with the ultimate goal of enabling local training institutions to directly deliver the training activities.

Scope

3. Consistently with identified needs, and agreed priorities, the training program would aim at the development of strategic and analytical skills of the targeted trainees in support of the implementation of sector reforms. In this context, the program would address transport policy and operational issues, with emphasis on pricing and resource mobilization, economic and financial analysis of capital investment projects, environmental assessment, liberalization and private sector development, and business administration. The above issues would be aggregated under three product lines of training activities, as indicated in the following. It is anticipated that some of the training modules could be jointly used in the delivery of two or more of the identified product lines.

4. Transport Management Development Program (TMDP). This product line would comprise three training activities, i.e., one to be delivered each year. Participant managers would be identified among public sector officials already involved, or likely to be involved, in the preparation and appraisal of transport investments financed by multilateral financial institutions, including the World Bank. Program contents would cover fundamentals of transport economics; the project cycle with emphasis on the economic, financial and environmental analysis of projects; infrastructure management systems; logistics management; and procurement. In addition, a module would be specifically focussed on the origin and role of, as well as on the procedures followed by, international financial institutions including the mobilization of co-financing from bilateral and multilateral sources.

5. Executive Program on the Management of Transport Operations. Three activities are also considered under this product line, i.e., one in each year. This Executive Program would address training requirements of public sector officials and of industry managers with a view to enable them to operate in an environment characterized by increasing enterprise autonomy and competitiveness. One of the topics to be covered would be sector organization in market economies, with emphasis on the role of the Government in setting up the regulatory framework for private sector operators. Other topics to be covered would include logistics, marketing and personal management, as well as cost-accounting and financial management of transport enterprises. The importance of Management Information Systems (MIS) would be addressed, as a basis for improved enterprise performance. The role of the financial system in support of industry development and rationalization would also be covered.

6. Construction and Consulting Industry Program. This product line would comprise the delivery of three training activities, i.e., also one per year. This Program would address training requirements of industry managers and regulators, toward the development of a market-based construction and consulting industry in the transport sector. Key policy-topics to be covered would include the policies, procedures and programs to address the major constraints to the development of a private-sector led industry; the building-up of the institutions required to ensure professional and quality standards; and the development of a business environment which encourages quality and competitiveness. Other topics to be covered would include business administration techniques for sector enterprises and the role of joint ventures with foreign firms as providers of seed capital and technology. The opportunities offered by Multilateral Development Finance Institutions to the development of a private-led and internationally competitive domestic industry would also be addressed.

Delivery

7. In line with the above assistance strategy, the training activities would combine lecture modules on the selected topics with small group workshops on subjects considered to be of more immediate relevance to the beneficiaries.

These subjects would be identified by the Program managers, in close cooperation with the targeted participants. The proposed delivery methodology would also emphasize field visits to selected transport facilities in Finland, so that participants would gain hands-on experience on how to practically address their problems.

Financing

8. Based on available information, it is estimated that a total of about US$900,000 equivalent, i.e. some US$300,000 per year, would be required to finance program preparation and delivery, including participants' identification and activity follow-up in the beneficiary countries. The cooperation program would be co-financed by the GOF, with EDINU's contribution amounting to some US$100,000 per year. In order to increase administrative effectiveness, parallel co-financing would be used. In this context, EDINU's contribution would be targeted at the financing of: (i) participation of non-Finnish lecturers/resource persons in the preparation and delivery of training activities; (ii) translation of training materials; (iii) provision of interpreters; (iv) travelling of participants to Finland; and (v) Bank's Task Management expenses. The contribution of the GOF is expected to be targeted at the financing of local costs in Finland, including services provided by domestic consulting firms and local logistics expenses.

Management

9. The program would be jointly managed by a Task Force comprising a Program Director to be appointed by the MOTC, by the Director of the IHME and by the responsible EDINU's Task Manager. The Task Force would ensure the day-to-day running of the Program, including joint missions to the targeted countries to identify needs and participants, and to follow up on the outcome of training activities. At least once a year, a meeting would take place between Higher-level Management from EDI and Senior Officials from MOFA and MOTC with a view to monitor program implementation, confirm the yearly funding levels, and approve the following year's activity program, including sub-regional targeting.

Case-Study

10. The Terms of Reference for the Case-Study on Infrastructure Management Systems are attached as Annex 1. The Case-Study would be immediately used as training material for the TMDP. It is expected to be completed by end-July, 1993, for a total cost of about US$200,000 equivalent to be funded by the GOF. EDINU would bear the additional costs to be incurred with the editing, translation, publication and diffusion of the Case-Study. At a latter stage, it is expected that the Case-Study would be integrated in the normal program of EDINU's activities worldwide.

Further Actions

11. A follow-up EDINU Mission would visit Helsinki for a period of one week on/or about March 8, 1993. The main objectives of the Mission would be to firm up with MOTC, the IHME, and the Program Director the: (i) specific contents of each Program activity; (ii) calendar for activity delivery, now tentatively scheduled to be initiated by October, 1993; (iii) local logistics arrangements; (iv) Activity Briefs, including the detailed budgets, for the activities included in the first year of the Program; and (v) progress in the preparation of the Case-Study on Infrastructure Management Systems. Benefiting from the Mission's presence in Finland, a first joint visit to the Baltic countries could take place during that period.

Attachment

Helsinki, December 18, 1992

Juhani Korpela
Secretary General
Ministry of Transport and Communications

Pedro Geraldes
Economic Development Institute
The World Bank

THE WORLD BANK/IFC/MIGA

OFFICE MEMORANDUM

ANNEX 1

APPENDIX 3

DATE: December 16, 1992

TO: Mr. Raimo Tapio, Finnish National Road Administration (FINNRA)

FROM: Pedro Geraldes, EDINU

EXTENSION: 3-6269

SUBJECT: Infrastructure Management System
Preparation of Case-Study

Background

1. The Economic Development Institute of the World Bank, through its Infrastructure and Urban Development Division (EDINU), is entering into a cooperative framework with the Government of Finland with a view to prepare and deliver a pluriannual training program. Program beneficiaries would be sector managers and trainers from Republics of the Former Soviet Union, especially the Russian Federation and the Baltic countries, and from selected Central and Eastern European countries. A key component of the training program is a Transport Management Development Program (TMDP) aimed at enhancing the strategic and analytical skills of participating trainees. It is anticipated that the majority of TMDP participants would be Government officials more directly involved in the identification and preparation of investment projects to be appraised by the Bank and other multilateral finance institutions.

2. The strategy to be followed in the preparation of training materials for the TMDP emphasizes the use of computer-aided decision-making techniques, based on economic benefit-cost concepts. Of paramount importance among these techniques are management systems allowing for a rational allocation of resources to the development and operation of infrastructure networks, including (but not limited to) roads. Such systems basically allow for an economic-based optimization of network expenditures, subject to budgetary constraints, based on the analysis of the trade-offs between user and infrastructure costs. As such, they have to comprehensively consider all the main expenditure items associated with the network under consideration, such as bridges and pavements in the case of road networks. Furthermore, they have to incorporate discounted cash flow techniques, so that investment efficiency indicators can be estimated for each investment alternative associated with a pre-specified level of budgetary availability.

Objectives

3. The chief aim of the assignment would be to upgrade the Pavement Management System (PMS) and the Bridge Management System (BMS), currently being used by FINNRA, in order to prepare a case-study on Infrastructure Management System (IMS) capable of meeting TMDP's training requirements. A summary structure of the IMS is presented in the Attachment. As such, the main objectives of the assignment are to:

(i) incorporate the quantification of Vehicle Operating Costs (VOC) into the BMS, toward the analysis of trade-offs between user and infrastructure costs;

(ii) allow for the consideration of diverted traffic effects within the BMS, through the incorporation of a minimum-cost VOC algorithm;

(iii) consolidate the BMS with the PMS, so that they can be jointly optimized under one budgetary constraint; and

(iv) prepare training documentation.

4. The assignment will comprise the following main steps:

(i) update the six sub-models integrating the PMS, including the basic condition and the cost data;

(ii) reserve three of the six PMS sub-models for bridges and select the bridge condition variables and their classification, estimate the transition probabilities for bridge deterioration, and define the menu of alternative actions for bridges;

(iii) calculate user costs for bridges and update them in the case of pavements;

(iv) update the software for the PMS and BMS for simultaneous run;

(v) optimize and estimate rates of return and other investment efficiency indicators for investment alternatives;

(vi) test software; and

(vii) prepare reports and review results.

Reporting

5. Main reports will be prepared in accordance with the following schedule:

(i) inception report by end-January, 1993;

(ii) final report by end-July, 1993; and

(iii) software package and documentation also by end-July, 1993.

Resources

6. You will lead the project team. It is anticipated that other team members would include a bridge engineer, a transport economist,a software specialist, and a statistician. The number of person-months required for the various tasks, as well as of the associated costs, is presented below.

Task	Person-months	Cost (US$)
0. Administration	1	13 300
1. Bridge: variables, probabilities, condition classes, min-path anal., actions	5	66 500
2. Data base software changes, data input	2	26 600
3. HIPS software changes	1	13 300
4. Calculation of rate of return	2	26 600
5. Analyses	3	39 900
6. Recurrent (adp, fax, trips etc.)		13 800
Total (US$)		200 000

Attachment

Structure of IMS